中国科学技术大学

University of Science & Technology of China (USTC)

W/Z+γ measuerment @ ATLAS

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University of Science & Technology of China (USTC)

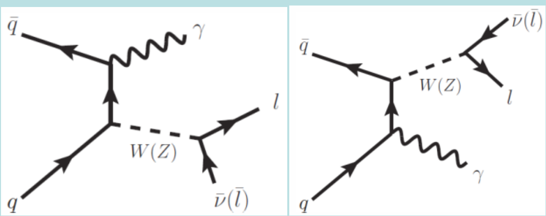
On behalf of ATLAS Collaboration

ICHEP2012

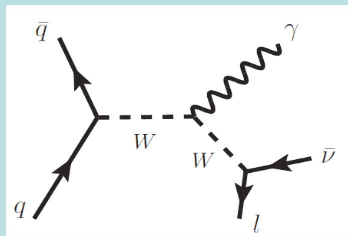
Melbourne, Australia

Motivation

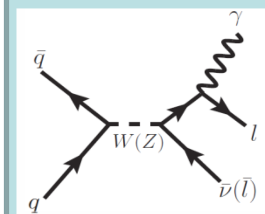
➢ **W($l\nu$)/Z(ll)+γ production measurement:**



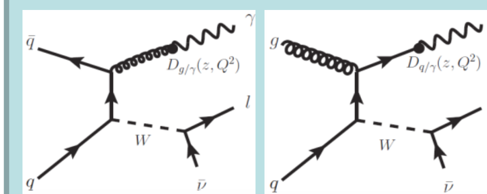
ISR: t/u-channel



s-channel TGC



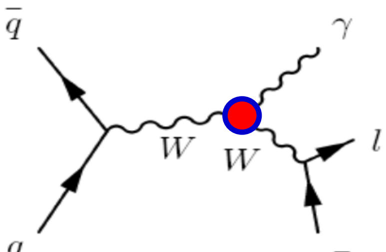
FSR



gluon/quark fragmentation

➢ **Searching anomalous triple gauge couplings (aTGC):**

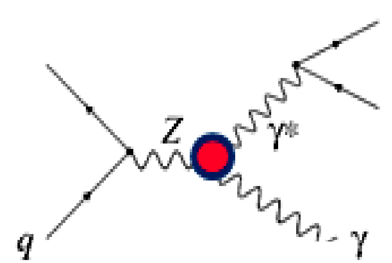
- **W magnetic dipole and electric quadrupole moment**



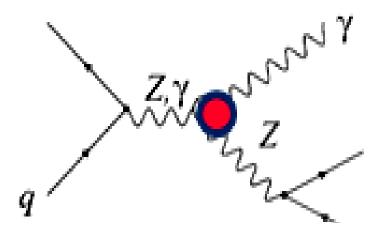
$$\begin{cases} \mu_W = \frac{e}{2M_W}(2+\Delta\kappa_\gamma+\lambda_\gamma) \\ Q_W = -\frac{e}{M_W^2}(1+\Delta\kappa_\gamma-\lambda_\gamma) \end{cases}$$

WWγ aTGC: $\Delta\kappa_\gamma$, λ_γ

- ***ZZγ/Zγγ*** **prohibited by SM**



Zγγ aTGC: $h^{\gamma}_{3/4}$



ZZγ aTGC: $h^{Z}_{3/4}$

- **Prior-LHC results**
  - + D0, 4.2fb^{-1} Wγ, PRL107(2011)241803
  - + CDF, 5fb^{-1} Zγ, PRL107(2011)051802
  - + D0, 6.2fb^{-1} Zγ, PRD85(2012)052001

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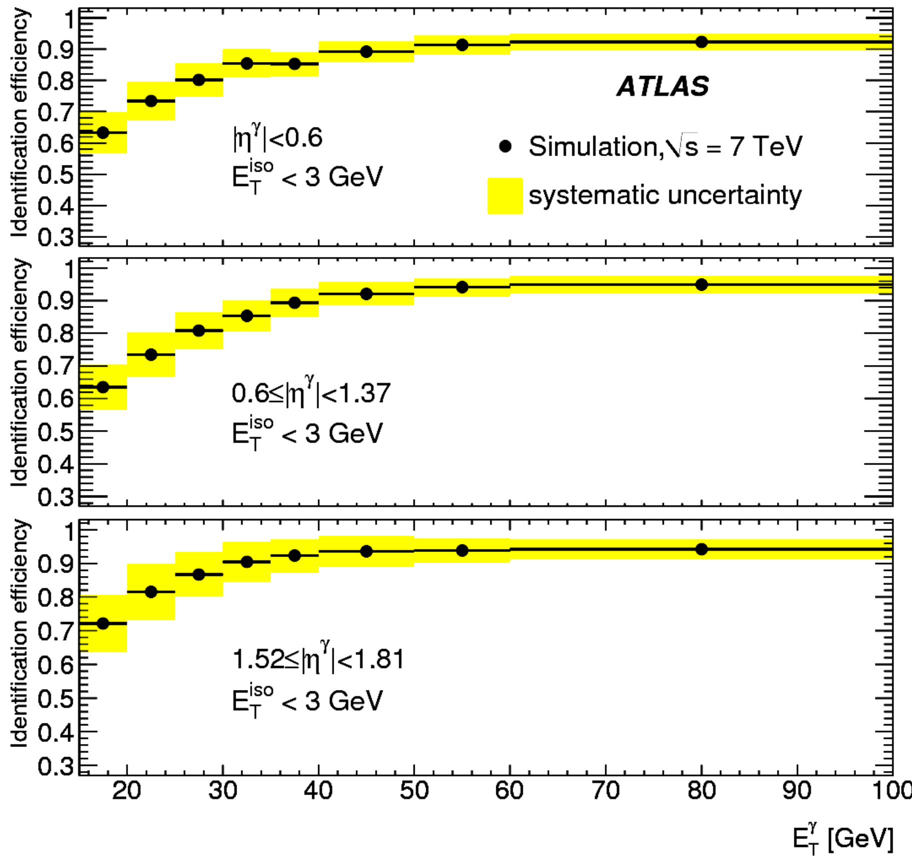
Event Selection

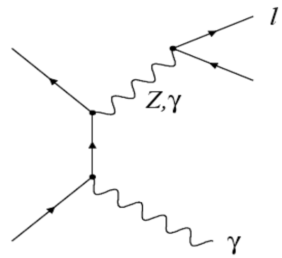
- ✓ *ATLAS 35pb^{-1} result as* **JHEP 1109,072**
- ✓ *ATLAS 1.02fb^{-1} result as* **arXiv:1205.2531**

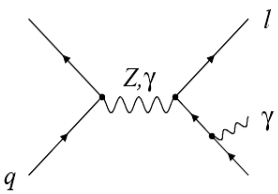
➢ **ATLAS 7TeV 1fb^{-1} (35pb^{-1}) data:**

- Lepton :
  - + e/μ p_T>25GeV, detector fiducial |η| coverage; isolated in calorimeter;
  - + Tight electron identification
- W/Z events : MET>25GeV, MT($l\nu$)>40GeV; M(ll)>40GeV
- Photon :
  - + p_T>15GeV, detector fiducial |η| coverage;
  - + Isolated in calorimeter
  - + Tight photon identification
  - + FSR suppression dR(l,γ)>0.7
  - + Simulation corrected to *Z→llγ data*
- Jet : p_T>30GeV, |η|<4.4, dR(j,γ/*lepton*)>0.6
  - → Inclusive (>=0jet) vs.
  - Exclusive (==0jet)

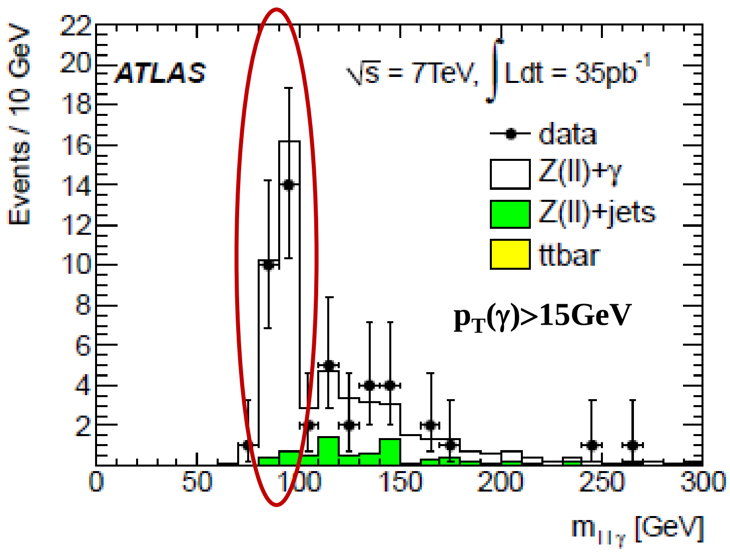


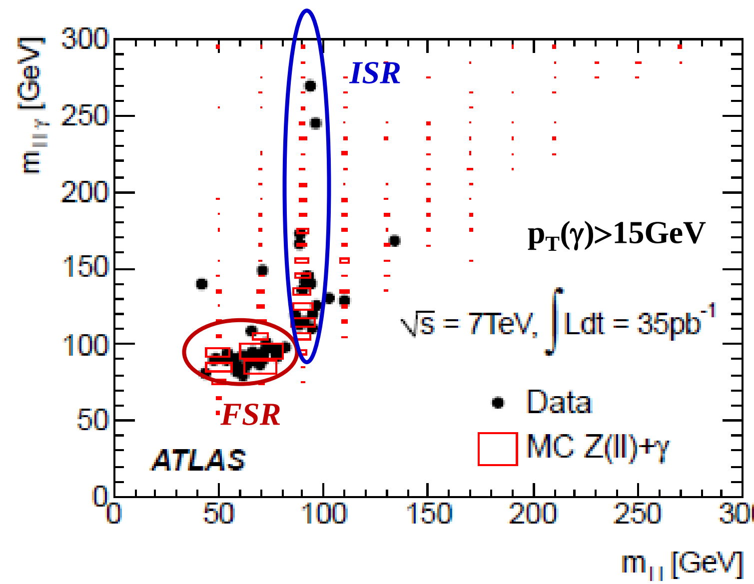
- **ISR/FSR vs. $p_T(\gamma)$ cut:**





ISR: $M(ll\gamma) > M_Z$ **FSR: $M(ll\gamma) \leq M_Z$**

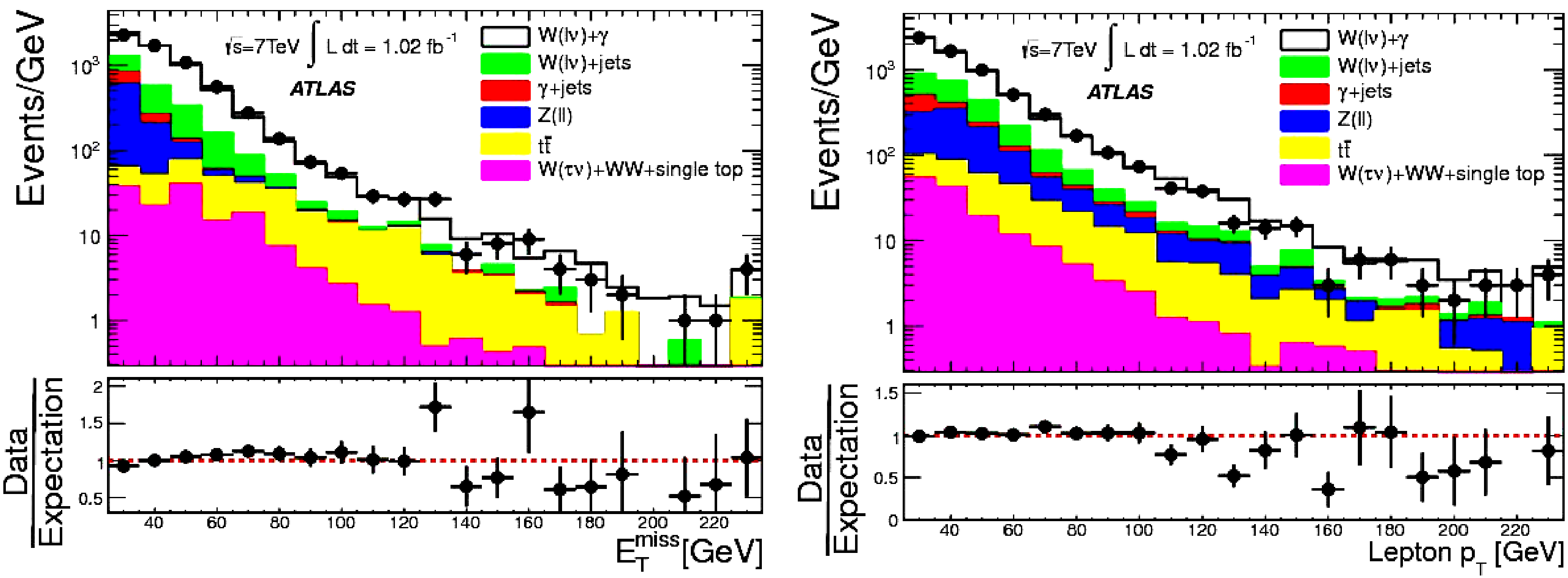




High photon p_T cut to suppress FSR as

$Z\gamma$: $p_T(\gamma)$>15, 60GeV; $W\gamma$: $p_T(\gamma)$>15, 60, 100GeV

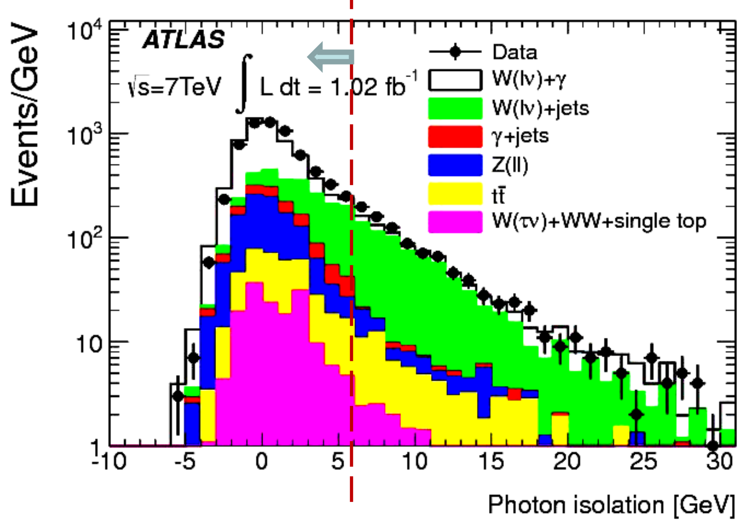
W($l\nu$)+γ control plot

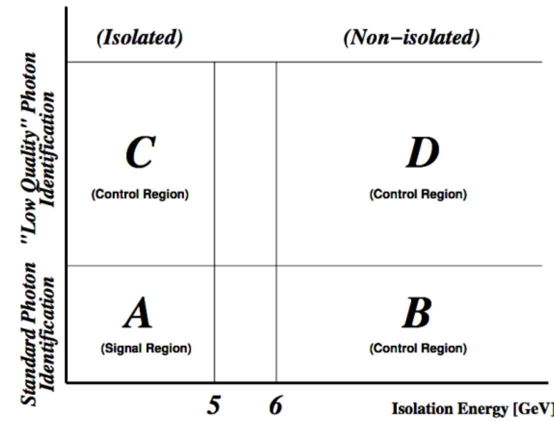


- **Electroweak background** derived from simulation
- **Dominant background, *W+jet* has to be estimated from data**

W/Z+jet background

- 2D sideband *jet*→ "*γ*" background estimation:
  - **Photon Identification**: based on calorimeter shower-shape
  - **Photon Isolation**: $IsoE_T^{30} = \left[\sum_{dR<0.3} E_T^i\right] - E_T^{\gamma}$





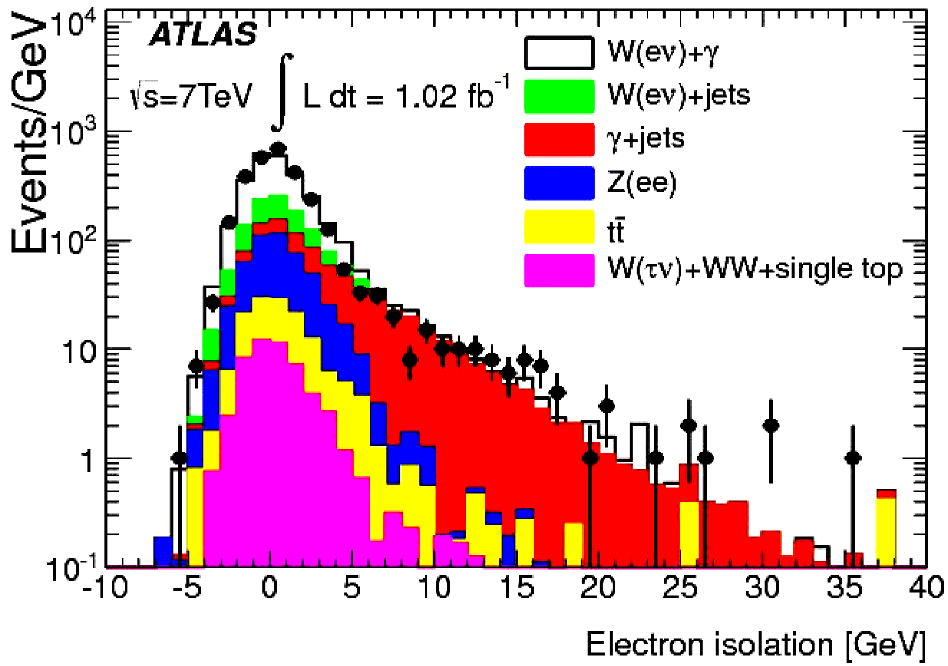
$$N_A = N_A^{W\gamma} + N_A^{Wjet}$$

$$N_{B/C/D} = N_{B/C/D}^{Wjet}$$

$$N_A^{Wjet} = N_B^{Wjet} \cdot \frac{N_C^{Wjet}}{N_D^{Wjet}}$$

Jet+γ background in *Wγ*

- **Date-driven *jet*→ "*e*/*μ*" estimation:**
  1) **jet+γ : real γ; non-isolated letpon from heavy b/c decay;**
  2) **Control region : MET<20GeV to extract faked "*e*/*μ*" isolation shape**

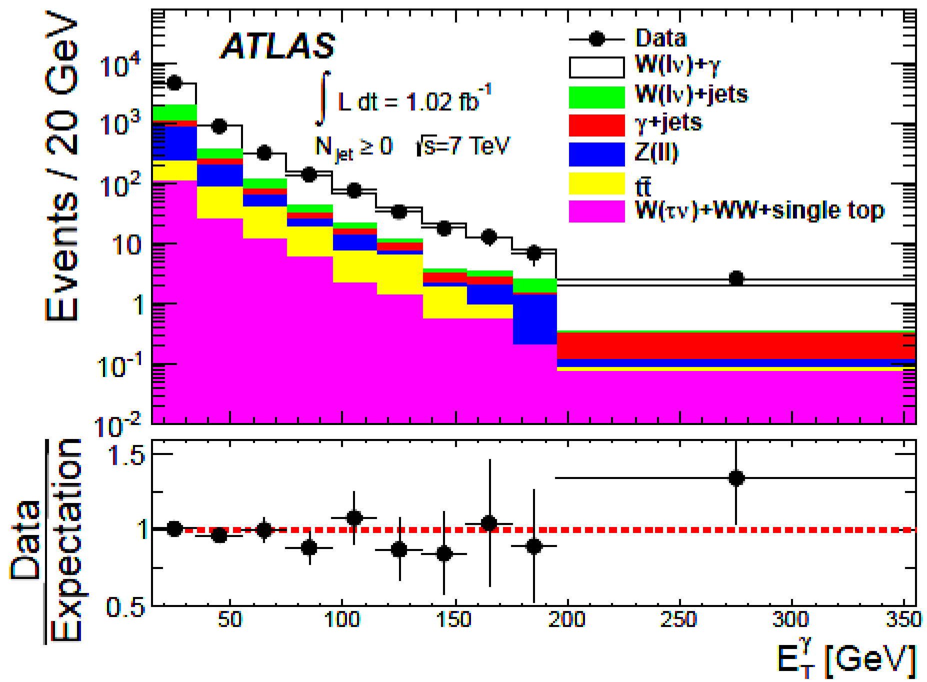


W(eν)γ :MET vs. isolation 2-d sideband

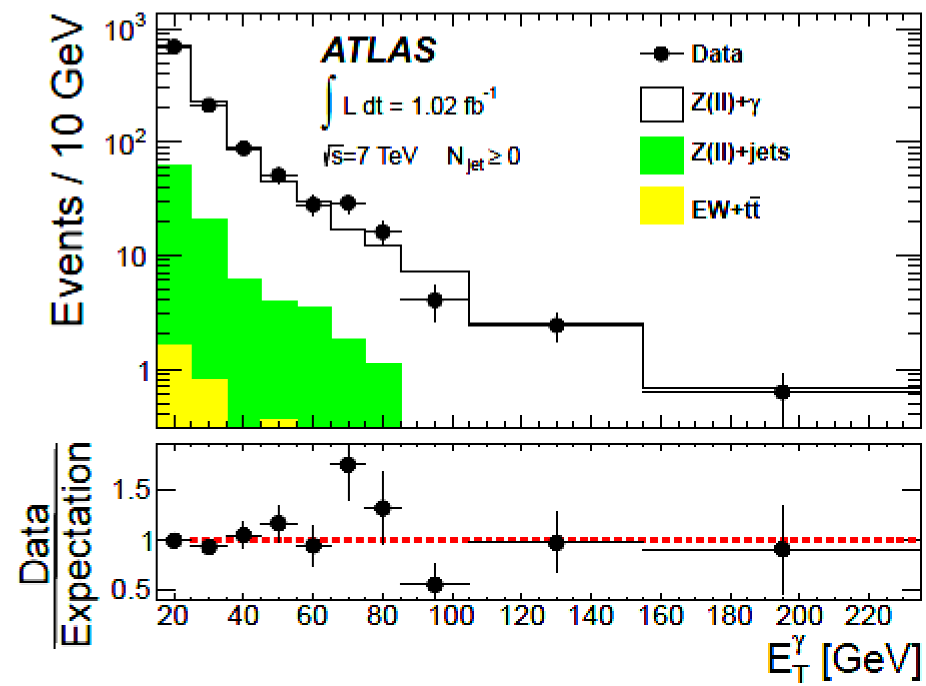
Signal event yield

- **Photon E_T spectrum:**

***W(lν)γ* inclusive**



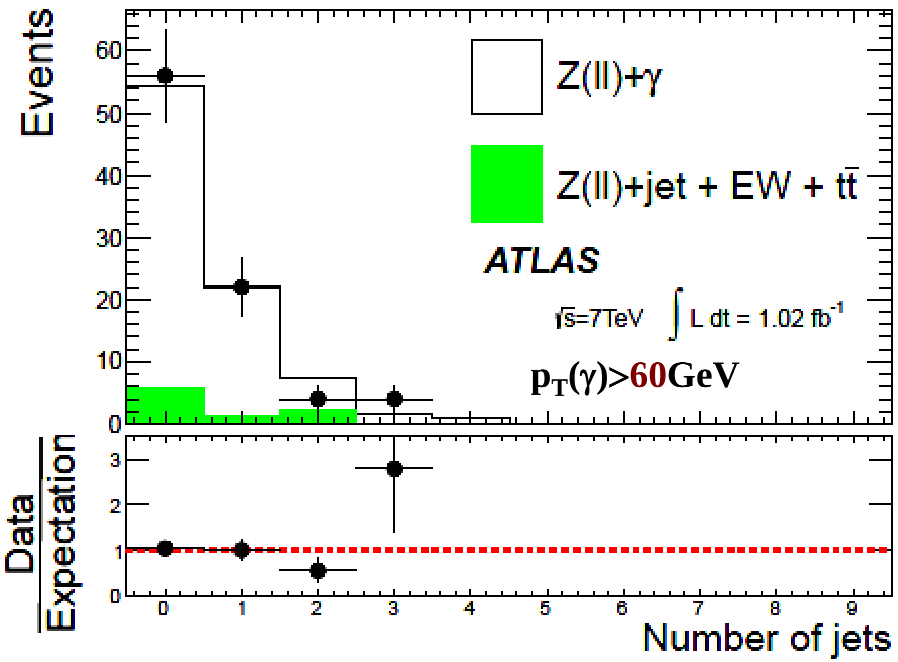
***Z(ll)γ* inclusive**



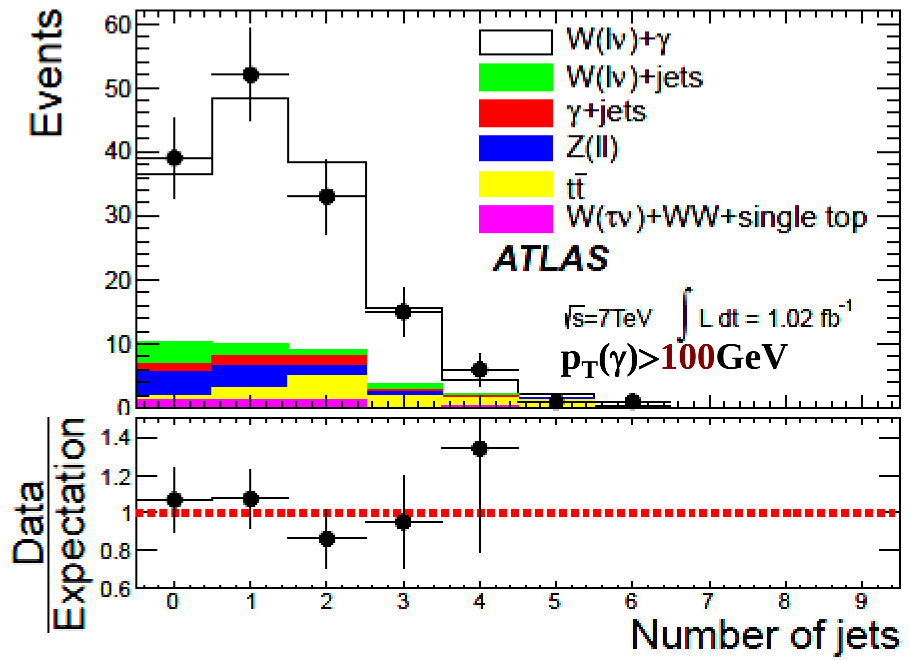
* Signal distribution normalized to the number of extracted data

- **Number of jet distribution:**

$Z(ll)\gamma$: $p_T(\gamma)$>60GeV



$W(l\nu)\gamma$: $p_T(\gamma)$>100GeV



Inclusive (>=0jet) vs. Exclusive (==0jet)

Cross section measurement

$$\sigma^{\mathrm{ext-fid}}_{pp\to l\nu\gamma(l^+l^-\gamma)} = \frac{N^{\mathrm{sig}}_{W\gamma(Z\gamma)}}{A_{W\gamma(Z\gamma)} \cdot C_{W\gamma(Z\gamma)} \cdot L}$$

$A_{W\gamma(Z\gamma)}$: **Detector Acceptance**

$C_{W\gamma(Z\gamma)}$: **Experimental selection efficiency**

L: **Luminosity** **1.024fb^{-1} ± 3.8%**

- **Unfold detector efficiency:**
  - \+ **Correction factor $C_{W\gamma(Z\gamma)}$ ~ 40 - 60%**
  - \+ **Systematic δ_C~ 10 %, dominated by photon identification & jet energy scale**

$$\sigma^{fid}_{pp\to l\nu\gamma(ll\gamma)} = \frac{N^{sig}_{W\gamma(Z\gamma)}}{C_{W\gamma(Z\gamma)} \cdot L_{W\gamma(Z\gamma)}}$$

$$\sigma^{ext\,fid}_{pp\to l\nu\gamma(ll\gamma)} = \frac{\sigma^{fid}_{pp\to l\nu\gamma(ll\gamma)}}{A_{W\gamma(Z\gamma)}}$$

- **Unfold for detector acceptance :**
  - $A_{W(Z)\gamma} = \frac{N_{fiducial}}{N_{extented\_fidual}}$

    Estimated from **Alpgen/Sherpa**

+ **Extend detector fiducial to a uniform lepton |η| coverage**

+ **Theoretical uncertainty on acceptance**

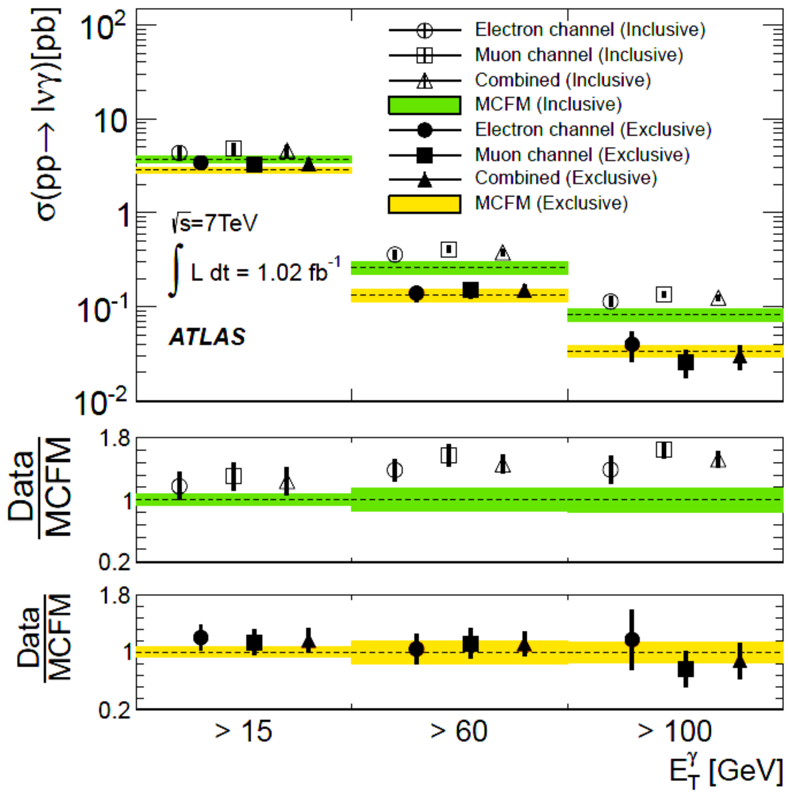
  $\delta_{Theo.} \sim$ **1-3%**

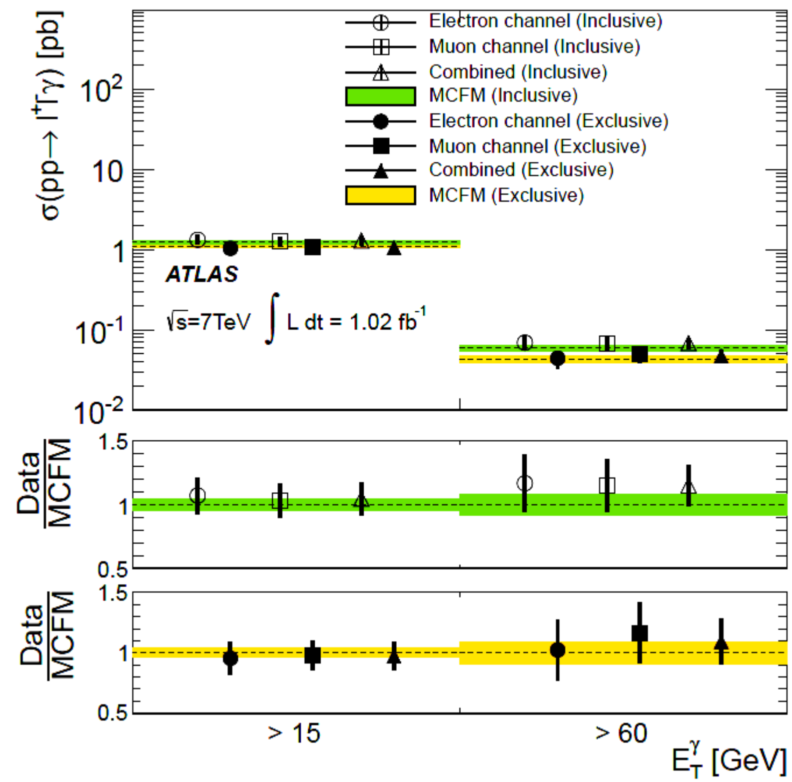
- **Compare to SM prediction:**
  - $\sigma^{ext\,fid}_{pp\to l\nu\gamma(ll\gamma)} = \frac{\sigma^{fid}_{pp\to l\nu\gamma(ll\gamma)}}{A_{W\gamma(Z\gamma)}}$

    Compared against **MCFM** (ISR + FSR + QCD NLO)

Differential cross sections

1) **Photon p_T>15,60,100GeV**; 2) **Inclusive** (≥0jet) vs. **Exclusive** (=0jet)





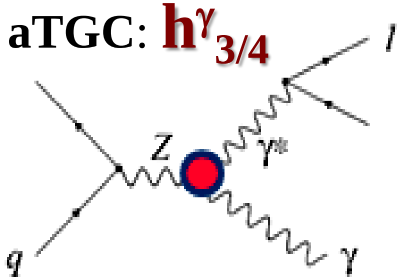
- **The Exclusive measurements are consistent with MCFM predictions (SM NLO)**
- **The Wγ Inclusive are higher than MCFM, especially in high $p_T(\gamma)$ region**
  → high order effects (NNLO and beyond)

Anomalous couplings

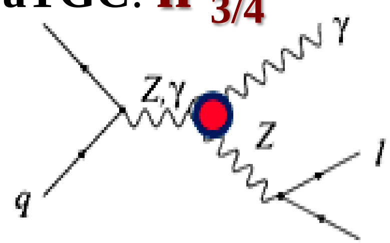
+ **aTGC $h^V_{3/4}$** : ***ZVγ*** **electric dipole / magnetic quadrupole transition moment**

+ **non-zero aTGC** **will result in increasing of W/Z+γ cross section, especially in high photon p_T region**

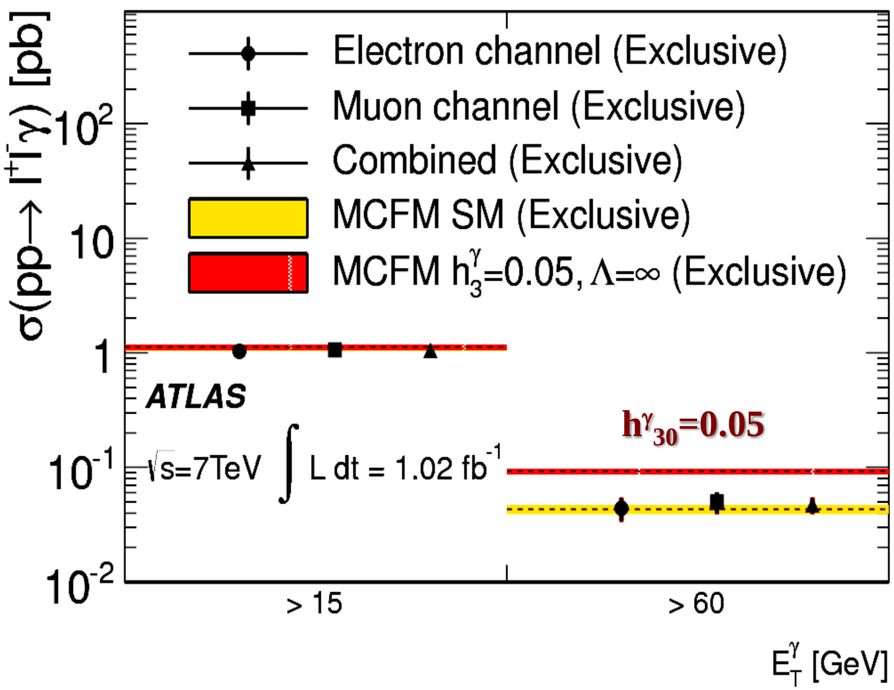
Zγγ aTGC: $h^\gamma_{3/4}$



ZZγ aTGC: $h^z_{3/4}$

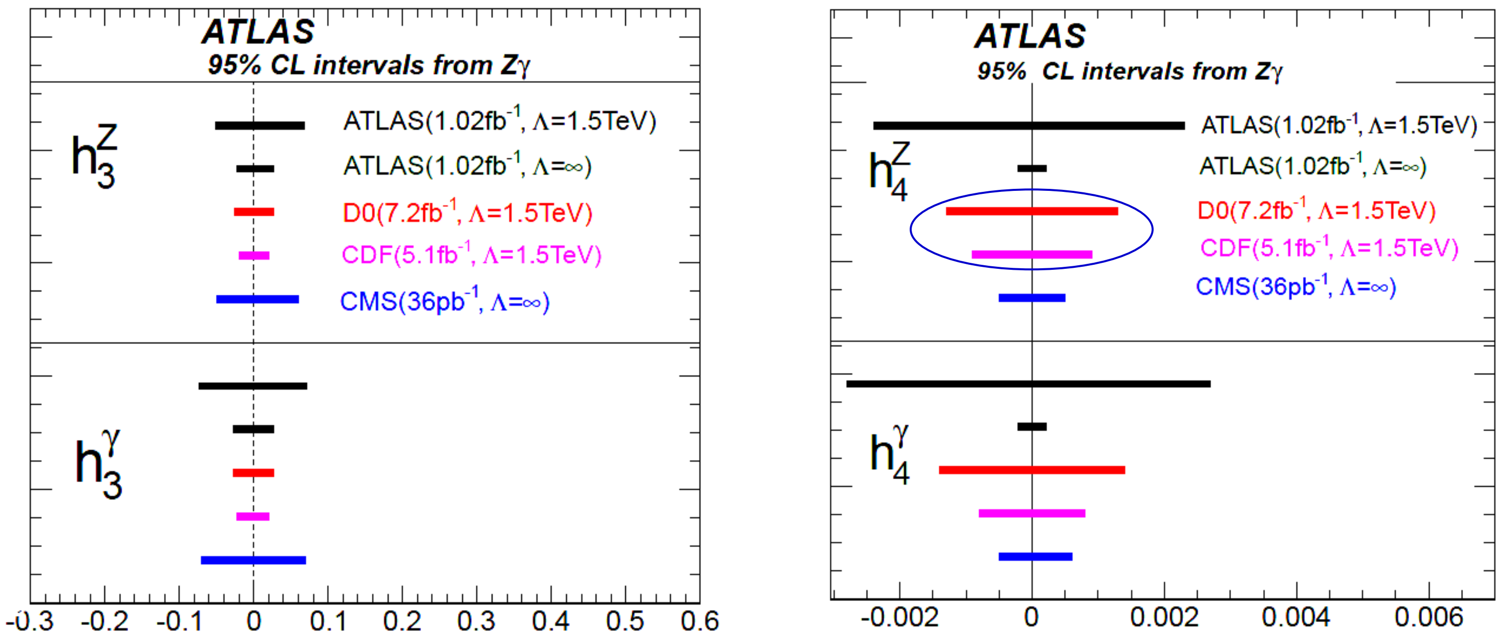


$$h_i^V = \frac{h_{i0}^V}{(1+\hat{s}/\Lambda^2)^n}$$



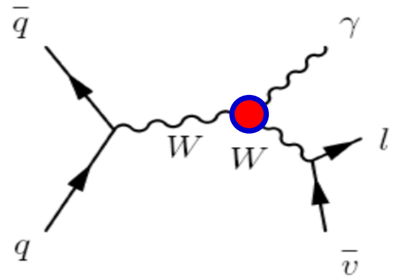
- **Extract *ZVγ* aTGC:**

+ **Exclusive *$E_T(\gamma)$>60GeV* measurement $\sigma_{Z\gamma}^{obs}$ against aTGC hypotheses $\sigma_{Z\gamma}^{aTGC}$**



+ **Bayesian probability with nuisance parameters to set limits**

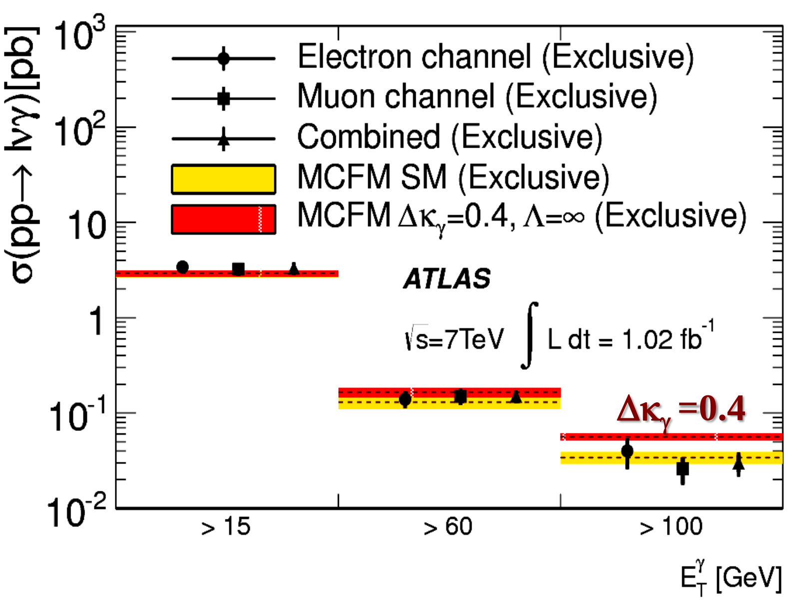
- **Extract *WWγ* aTGC:**

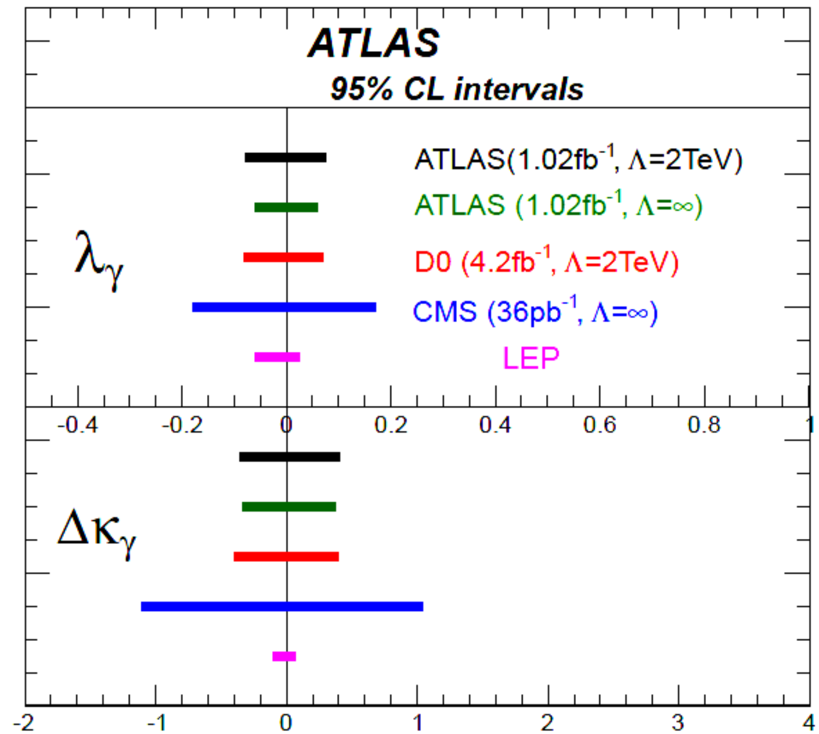


WWγ aTGC: $\Delta\kappa_\gamma$, λ_γ

Exclusive *$E_T(\gamma)$>100GeV* measurement $\sigma^{obs}_{W\gamma}$

against aTGC $\sigma^{aTGC}_{W\gamma}$ hypotheses





Summary

- **The differential cross section *$W(l\nu)\gamma/Z(ll)\gamma$* measured @ 1fb^{-1} 7TeV ATLAS:**
  - **Exclusive (=0jet) measurement is consistent with SM NLO**
  - **High order effect (NNLO and beyond) is observed in Wγ inclusive (≥0jet) data, especially in high photon $p_T(\gamma)$>60GeV region**
- **Limits on anomalous TGC couplings derived from high photon pT spectrum**
  - **WWγ aTGC results better than the existing Tevatron limits**

Backup slides

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Signal event yield

➢ **W(*l ν*)*γ*:**

	$pp \to e\nu\gamma$	$pp \to \mu\nu\gamma$	$pp \to e\nu\gamma$	$pp \to \mu\nu\gamma$
Region	$E_T^\gamma > 15$ GeV $N_{jet} \geq 0$		$E_T^\gamma > 15$ GeV $N_{jet} = 0$	
$N_{W\gamma}^{obs}$	2649	3621	1666	2238
W+jets	439 ± 108	685 ± 162	242 ± 68	473 ± 128
γ+jets	255 ± 58	67 ± 16	119 ± 34	28.9 ± 7.4
EW	405 ± 53	519 ± 67	229 ± 30	366 ± 48
$t\bar{t}$	85 ± 11	152 ± 20	1.6 ± 0.4	8.1 ± 1.3
$N_{W\gamma}^{sig}$	1465 ± 139	2198 ± 183	1074 ± 91	1362 ± 145

- Dominate background as **W+jet**(“**γ**”), **γ+jet** (“**e**”), **Z(*ll*)**

➢ **Z(*ll*)*γ*:**

	$e^+e^-\gamma$	$\mu^+\mu^-\gamma$	$e^+e^-\gamma$	$\mu^+\mu^-\gamma$
Region	$E_T^\gamma > 15$ GeV $N_{jet} \geq 0$		$E_T^\gamma > 15$ GeV $N_{jet} = 0$	
$N_{Z\gamma}^{obs}$	514	634	376	495
$N_{Z\gamma}^{BG}$	43.7 ± 16.5	56.8 ± 16.2	29.3 ± 11.0	39.3 ± 15.8
$N_{Z\gamma}^{sig}$	471 ± 28	578 ± 29	347 ± 22	456 ± 27

- Dominate background as **Z+jet**